NATIONAL SCIENCE FOUNDATION
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OFFICE OF THE
ASSISTANT DIRECTOR
FOR MATHEMATICAL AND
PHYSICAL SCIENCES

FEB - 6 2004

Dr. Marvin L. Marshak
School of Physics and Astronomy
University of Minnesota-Twin Cities
450 McNamara Alumni Center
Minneapolis, MN 55455-2070

Dear Dr. Marshak:

With this letter I am notifying you that your proposal for a deep underground laboratory, PHY-0335435, "SOUDAN: A Proposal for National Underground Science and Engineering Laboratory (\NUSEL\)", is being returned without prejudice. As you can see from the enclosed documents, your proposal was well regarded scientifically. In addition, your proposal and the other unsolicited proposals received by the Foundation have played an important role in shaping the best possible approach to the planning process for the development of a proposal for a possible underground laboratory or laboratories. We have gained much useful information as a result of the time and effort you spent in submitting this unsolicited proposal, and we wish to emphasize that our action does not negatively reflect on the scientific merits of your submission. All four unsolicited proposals are being returned at this time.

Our decision to return this proposal reflects altered circumstances that affect all planning for a possible underground laboratory. The site review panel that named Homestake as "the most favorable site" for a deep underground science laboratory also expressed serious concerns about potential adverse consequences of flooding and the "potential for destabilizing the flooded region" by allowing the site to be flooded and then subsequently dewatered: "Important reasons to continue pumping include maintenance of mine stability, avoidance of equipment replacement or damage, consistency with existing operating approvals and preservation of the rock mass environment." During the summer of 2003, the Homestake mine owner discontinued pumping water from the site. Since then, water has risen to an unknown depth, with uncertain ramifications for the viability of the site for science.

It is prudent, therefore, to consider again all possibilities for an underground lab, including a reevaluation of the suitability of Homestake as a site. We want to clearly and unequivocally state that this reconsideration does not eliminate Homestake as a possible site. Rather, we are now focused on establishing a framework for consideration of the science that the community wishes to pursue and the best possible location or locations for that science.

To assist the community in directing its energies to the most potentially productive ideas and to encourage valuable collaborations, NSF will – in the near future – issue the first in a staged three-part series of solicitations for sequentially more specific planning activities.

The first solicitation will provide support for one or more interdisciplinary teams to develop a preliminary plan of research activities requiring deep underground access, to aggregate the proposed research in appropriate science modules, and to define the physical requirements needed for each module. A second solicitation will fund grants for conceptual planning of infrastructure as related to the site. A third solicitation will fund technical designs for the underground infrastructure, detailed geological characterization and environmental permitting, and development of management plans. It will also support development of plans for an initial suite of research activities, as well as cost estimates and safety requirements. We encourage all interested stakeholders to submit future proposals in accordance with these solicitations.

These solicitations do not signify that NSF or any other agency of the federal government has approved the construction and operation of a deep underground laboratory and a corresponding suite of experiments. Like all major research projects contemplated for funding, an underground lab would have to compete for priority and resources with dozens of other promising programs. Moreover, even if NSF determined that a compelling case could be made for an underground laboratory, that does not assure its inclusion in the President's budget request – or Congressional appropriation of funds for the project.

Rather, the solicitations will enable the Foundation to pursue six overarching objectives for developing a proposal for the construction and operation of an underground laboratory. The process for developing plans and proposals for underground science must:

1) be open and transparent to all interested parties, including civic, cultural, and environmental groups;
2) be inclusive of all scientific and engineering communities with an interest in an underground science;
3) produce a reliable estimation of cost and schedule for the lifecycle of the project;
4) include detailed plans for mitigating the hazards of operating such a facility;
5) include detailed plans for education and outreach;
6) cultivate strong regional participation.

NSF will convene an informational meeting to explain the goals of the upcoming solicitations and to discuss NSF requirements for developing proposals.

We invite and encourage your participation in this process. The work you have already undertaken in the interest of developing a proposal for an underground lab will be of great value to this new proposal planning process. We are optimistic that this process can ensure development of the best possible proposals for an underground laboratory.

If you have any questions regarding this matter, feel free to contact either Dr. Richard Boyd or Dr. Eugene Loh.

Sincerely yours,

Michael S. Turner
Assistant Director
Directorate for Mathematical
and Physical Sciences

Enclosures

cc: Kevin J. McKoskey

Title:SOUDAN: A Proposal for a National Underground Science and Engineering Laboratory (NUSEL)

Institution: University of Minnesota-Twin Cities

NSF Program: Underground Physics

Principal Investigator: Marshak, Marvin L.

Rating:

Review:

What is the intellectual merit of the proposed activity?

This is a proposal to provide the infrastructure for a large and deep underground laboratory through a major expansion of the present Soudan underground laboratory.

There is little discussion of scientific issues in the document, nor is this necessaryùthe scientific case has been made by the Bahcall Panel. There is no doubt that important and timely scientific issues could be addressed.

**Attractive Features of Proposal:

The proposers and the University of Minnesota have a long track record in managing an underground laboratory of significant size, with construction expenditures not greatly different from those anticipated in the expansion.

The principal part of the laboratory is a green site, and will not be troubled by issues of non-optimum structures, of replacement of obsolescent equipment, etc. At the same time the existing laboratory will provide certain infrastructure advantages early in construction and will permit smaller new experiments to proceed on a fast time scale.

Some new scientific and technical directions are proposed and appear of interest: neutron oscillations, economic geology, pumped storage.

Capability suitable to presently conceived experiments (which appear to require 4000 mwe) and possible future experiments which may benefit from greater depth.

Access by truck for large shipping containers, using an imaginative inclined racetrack, following an earlier apparently successful development in Finland.

Apparently, the capability to delay development of the deepest layer, at little cost. This would permit one to proceed with a lower cost facility that meets present requirements, while delaying construction of the deepest part of the mine until the precise needs and requirements become clear.

What are the broader impacts of the proposed activity?

The proposal addresses issues of public outreach, building on the demonstrated commitment of its present visitor program. Issues related to the welfare and security of the nation are addressed in some detail. The facility could make possible a range of activities spanning several fields.

Summary Statement

After finishing the above part of this review I spoke with the relevant program officer, and learned the NSF had already made a decision to limit their future considerations to a possible Underground Laboratory at the Homestake mine. And I read the NSF Site Panel Report. As a result, I"ll limit my further consideration to the following remarks.

If for any reason use of the Homestake mine becomes untenable, I conclude that Soudan is a worthy backup to Homestake. Indeed, based on the proposal I would have rated Soudan above Homestake. While I defer to the geology experts on the technical aspects, it does not seem to me that the possible additional costs are out of line, since the present proposal has 40% contingencies, compared to the 50% mentioned by the Site Committee, yet the costs appear similar to Homestake.

The use of a 'mainly' green site may involve some delays, but there are advantages, in the possibility of providing more precisely the facility capability required and avoiding the need for upgrading old equipment, some pre-WWII. Nor is it clear that major new experiments will be ready on a shorter time scale.

Title:SOUDAN: A Proposal for a National Underground Science and Engineering Laboratory (NUSEL)

Institution: University of Minnesota-Twin Cities

NSF Program: Underground Physics

Principal Investigator: Marshak, Marvin L.

Rating:

Review:

What is the intellectual merit of the proposed activity?

Neutrino astronomy was born with the first observation of neutrinos emitted by the sun in a deep U.S. mine. The observed rate disagreed with the conventional description of the nuclear processes by which the sun burns. The Sudbury Neutrino Observatory (SNO) located in a deep mine in Canada demonstrated that the solar neutrino beam 'oscillates,' proving that neutrinos have mass. The discovery represents a dramatic 'proof of concept' of particle astrophysics: a fundamental discovery in particle physics emerged from astronomical data. The rapid rise of particle astrophysics as a discipline at the boundaries of astrophysics, cosmology and particle physics made this success possible. We have recently witnessed an explosion of new experimental techniques leading to completely novel as well as more sophisticated and more sensitive experiments in particle astrophysics. Among these, some must be deployed underground to be adequately shielded from the cosmic radiation at the surface of the earth; recent second-generation experiments such as SNO itself require increased depths. Because SNO's depth was not accessible at the only existing underground laboratory, the Gran Sasso National Laboratory in Italy, the SNO collaboration, like many other around the world, had to create its own infrastructure, in this case in a deep nickel mine in Sudbury, Ontario. This is less than ideal and, with the rapidly increasing interest of the astrophysics and particle physics communities in a large variety of new underground experiments, it would be good planning to provide the US scientific community with a centralized underground facility, preferably providing access to increased depths compared to Gran Sasso. The convenience of a nearby infrastructure that can support future experiments will undoubtedly further invigorate this exciting field.

It should be noted that this may not even be the most compelling argument for a national underground facility. Convincing arguments have been made in the context of geoscience, material science and national security.

In summary, the scientific case for an underground laboratory is totally compelling. It is made convincingly in two documents appended to this proposal. This particular proposal suggests three more science opportunities: the study of nucleon-antinucleon oscillations which could lead to further insight into the mechanisms responsible for the baryon asymmetry in the Universe, geo-economic studies of the ancient sub-sea floor

hydrothermal system and, finally, the study of pumped hydroelectric energy storage. Undoubtedly, these are just examples of novel exploitations of an underground facility that will emerge once a national laboratory becomes reality.

What are the broader impacts of the proposed activity?

The track record of the particular management team essentially guarantees that an excellent education and outreach program will be associated with the project.

Summary Statement

The scientific case for the creation of an national underground laboratory justifies an "excellent" rating for this proposal. However, this reviewer does not have the expertise to validate the management and budget. The rating covers the science case only.

Title:SOUDAN: A Proposal for a National Underground Science and Engineering Laboratory (NUSEL)

Institution: University of Minnesota-Twin Cities

NSF Program: Underground Physics

Principal Investigator: Marshak, Marvin L.

Rating: Excellent

Review:

What is the intellectual merit of the proposed activity?

This proposal addresses a topic of first importance for particle, nuclear and astro-particle physics. That is, the creation of a deep underground national laboratory (NUSEL) in the U.S.A. The science and engineering disciplines of geology, geophysics and geobiology would also be served in a NUSEL. My expertise is in the physics area and I can attest to the intellectual merit of that science which would be done in such a laboratory. In both general and specific terms, the present and potential importance of the science has been widely discussed, documented and disseminated. Most recently, the NRC/NAS report ('Neutrinos and Beyond') has reviewed this science in the specific context of the possible need for an underground laboratory. Its authoring committee (NFAC) strongly endorsed the value of a NUSEL and emphasized the criteria a NUSEL should possess.

This proposal, to expand the present lab in the Soudan ex-mine into a NUSEL, presents a thorough, ~ 6 page table discussing and outlining the science topics which would be done in the expanded lab as well as the specific needs (depth, space, cleanliness, etc) and importance of each topic. Their presentation is completely consistent with the current thinking in the physics community as represented by future planning reports of NSAC, HEPAP and NAS/NRC. The intellectual merit is not at question at all.

The principal, present question is to what extent would the new Soudan NUSEL offer the capability to serve this science and the community that would use it. The proposers have done their homework well and have attempted to address nearly every issue raised about a NUSEL at such community workshops at Lead and NESS as well as the criteria specified by the NFAC. To wit: depth and quality of overburden, differences among detector sizes and working materials, access, management and support facilities to name some principal ones.

With the possible demise of the widely favored Homestake ex-mine as venue for a NUSEL, scrutiny of this Soudan proposal takes on increased importance. Initially, I was a skeptic that anything remotely likely to provide a widely satisfactory NUSEL at Soudan would be possible. I believe they have gone a long way toward suggesting ways in which Soudan can be modified to satisfy most of the essential criteria.

They envision a three Phase build up to a full lab. As is well known, there is presently at Soudan an on-going research program at the 710m depth with detectors for dark matter and for beam neutrinos oscillating from FNAL. The latter is completing major

construction and when that portion is concluded a certain amount of beneficially occupiable space for initial aspects of a NUSEL is said to come available this year. It is suggested these might involve initially a low background testing facility (an essential user facility) and some space for testing other detectors" parts or concepts where some overburden is essential. Phase II would initiate the major construction of access to depths of 1400 and 2500 m. These three depths (710, 1400 and 2500 m) and the types of experimental halls that would eventually be placed at them are very desirable for the spectrum of experiments currently anticipated by the community. Access to a NUSEL via vertical shafts with hoists or via horizontal 'drive-in" has been a continual issue in the NUSEL debates. The ability to bring 40-ton containers or massive detector parts in a straight-forward way is a sine-qua-non no matter how it is to be done. The new (or existing) tunnels under overburdens provided by mountains (such as Gran Sasso, Kamioka and the potential San Jacinto) have always been considered a strong plus. Mines or ex-mines (such as Homestake and Sudbury---and SoudanII itself) with limited hoist capacity and shared use have always been considered a strong minus. The WIPP facility is the sole vertical access facility with a major carrying capacity; however, WIPP for many other reasons does not satisfy sufficient other criteria to be a NUSEL. Soudan has come up with unique (but inspired by a Finnish mine) solution to access for both equipment and experimenters and support personnel. It would have a spiral, rather steep (1:7 grade), 'road' for vehicle-carried 40-ton loads and a vertical-rise shaft for personnel and lighter equipment up to 20 tons. While this has great appeal in principle---24/7 access for experimenters and container-size loads (surface-to-2500m in a few hour period)---it seems to me likely to be very costly, pose safety issues due to steepness and causes me to wonder if two successive WIPP-type lifts might be a viable and/or superior alternative. (I am not a knowledgable mining or geology person; however.) I am intrigued by it, nonetheless, as a possible solution. Phase III would see the experimental-proposal-driven construction or completion of the final cavities and their detectors. The whole process from PhaseIÓPhaseIII expected to extend through to some six years. That is faster than I would guess it could be done but the sequencing is right since the detailed science experimental program will not be known until later as it evolves. Clearly ---even as the proposers themselves say---the further geological studies and preparation of the technical design report will bring these issues onto more factual basis. For example, how certain is it that there are suitable geological and rock conditions for the two deepest labs at the two expansion sites under consideration? In the meantime I believe they are on the right track but they are very skimpy and not well focused on what more will be needed in infrastructure (shops etc) for the national and international community of users whose experiments will make the place worth having in the first place.

They mention that a 'plus' for Soudan is that there is already a neutrino beam pointed at it from FNAL. While this is surely a 'plus' presently it is not at all clear that it in itself will be broadly useful in the future or a unique advantage. Nonetheless it should be counted for something positive.

Management models for other NUSEL proposals considered so far have been mixed bags from my viewpoint. They have each had different strong and weak points but

realistically they also realized that some parts ---specifically how the local management would interface with the scientific and other non-fiscal-line communities---would probably be evolutionary but nonetheless needed to be clarified early-on. There are similarities and some important differences in this Soudan proposal. For getting it built, having the Regents of the University and the State of Minnesota involved at the start in the ways described has great appeal to me. There is a crispness of powers and chain of responsibility with a track record in projects of some size that encourages a certain amount of confidence --- at least for an outsider. As the proposal points out, having a project considered for expansion rather than "green field" relieves some potential show-delayers or show-stoppers. It is true that some of the academic PI"s and the SoudanII personnel have had dozens of years" experience creating the original site and its protocols with the State. They have been involved in its expansion for MINOS. However, creating a NUSEL at Soudan and creating it as a vital national lab is a bigger challenge than any one of them have faced and I am not sure that some other version of what they propose ---- still involving them in senior directorial/ management positions----does not need to be augmented by more widely experienced project personnel. They are deliberately, and wisely vague, on the scientific oversight and scientific programmatic structure which might obtain. They are open to suggestions and they will surely get more than they want!
There are plenty of models to be considered.
The total request for funds in this proposal is $276M (with 50% contingency) and $230M (with 25% contingency). The method by which they came to these figures is discussed clearly in the proposal. As the proposal states, the sum is in line with other NUSEL proposals giving some consideration to what items are mutually included. It is certainly too early to know how meaningful these comparisons are given the historical knowledge of the specific rock sites within Homestake and the lack thereof for the new regions near Soudan.

What are the broader impacts of the proposed activity?

On this second criterion for merit review: the broader impacts of the proposed work; the proposers have addressed this directly. I may be selective in what appealed to me the most. It should be noted that by the nature of the facility they are proposing and with the diverse topics that will be studied there, what is proposed has impacts well beyond a single physics or geology or biology discipline. It will facilitate cross-disciplinary fertilization by the very nature of such a lab.
The NSF is one of the agencies responsible for improvements in the arsenal of major research instruments for U.S. science. This laboratory could certainly be considered a truly major instrument in and of itself; however, many of the detectors that could be housed there will also be adding to that arsenal of instruments.
The proposers have suggested three applications that in the prior proposals for other labs were not discussed. I was particularly struck by the idea of pumped hydroelectric storage. It seems a stretch that it will be one of the things realized (and is not a

rational to build the lab); however, it is an intriguing idea that could lead to pilot studies being done there should the lab be constructed as they propose.
The education and outreach program at Soudan has been well established for some time and they propose to build upon that strength as they have recently done through cooperation with FNAL now that MINOS is part of SoudanII Lab present experimental program.
They also suggest that Northern Minnesota is an economically dying area that would benefit indirectly from the presence and activity of the lab. However, from the education point of view for minorities they mention a potentially important role they might play with the Native American tribes and tribal college within a 200-mile area.
Although none of these outreach proposals are fully developed nor is all the seedbed in place, I believe the PI"s intentions are serious and we should wait for further developments.

Summary Statement

In summary, I believe this proposal must be taken as a serious contender to be a genuine U.S. National Underground Science and Engineering Laboratory. They certainly should be encouraged to proceed to a technical design proposal. At this present stage of proposal development I give it an excellent.
I do not feel that it has the strength of what Homestake could have been particularly with respect to the knowledge of the rock at depth, the wide variety of experimental venues possible immediately or in the future, the user facilities incorporated into that plan and the surer knowledge of the ultimate construction costs. On the latter, I must defer to experts.
They note in their comparisons to the other potential sites their relative strengths and weaknesses. I found much to agree with in the points they compared and which are pluses and which minuses. Although I would not agree that expanded Soudan is obviously the best, what is proposed warrants the awarding of sufficient funds to keep them strongly in the game as the national situation clarifies in the coming months and year. Let"s make sure it is not years --- the science warrants a speedy resolution.

Title:SOUDAN: A Proposal for a National Underground Science and Engineering Laboratory (NUSEL)

Institution: University of Minnesota-Twin Cities

NSF Program: Underground Physics

Principal Investigator: Marshak, Marvin L.

Rating: Excellent

Review:

What is the intellectual merit of the proposed activity?

The authors propose to build a multipurpose underground laboratory to conduct frontier scientific investigations in nuclear physics, particle physics and goescience and to undertake major projects in geoengineering. The proposed laboratory would extend the existing facility at Soudan. Numerous high-level panels, including panels of the National Research Council, have rated the science that could be done at an underground laboratory extremely highly. Such a laboratory could address some significant scientific topics, such as the nature of dark matter, which is a mystery, the nature of neutrinos, which is a mystery, and the stability of nuclear matter, about which we still know so little. Moreover, if the proposed laboratory were able to sustain a long-term vigil we could become beneficiaries of a significant amount of information about matter under extreme conditions when the shockwave of the next galactic supernova sweeps past the Earth.

This well written proposal is one of the most exciting I have read in recent years. What I find particularly impressive is that each component of the proposed multidisciplinary laboratory is interesting in its own right. This is not a mere cobbling together of disparate parts, but a serious plan (with very strong state and national support) to build a truly multidisciplinary laboratory in the United States. I know very little about energy storage and geoscience, but I find the ideas proposed to be inspiring. Since there is no question that the proposed science is first-rate, the only significant issue is this: Is the plan credible and do the proponents have the wherewithal to execute it? The answer, I believe, is an unequivocal "yes". The authors have proposed a plan that is coherent and well thought out. Indeed, it is the most credible plan I have seen for establishing a national underground facility. Moreover, given adequate funding, I believe the proponents can make the plan work. Adequate funding may, however, imply a contingency greater than 50%; but this is very hard for me to judge.

Here is the basic case, which I endorse wholeheartedly: The new laboratory would build on Soudan, a successful, functioning underground facility, with a highly experienced competent team already in place. The proponents, themselves, are highly experienced competent individuals. Outreach to the community is well-established. Therefore, the quickest path to a world-class national underground laboratory is to extend Soudan. Finally, a crucially important point: Science would

start immediately at the new laboratory using the existing Soudan infrastructure. That being said, however, this proposal is only credible as a cutting edge research facility because of the proposed Phase 2, which will extend the laboratory to much greater depths. Phase 2 is therefore crucial.

If the United States wishes to become a leader in underground science, this proposal presents a credible plan for getting there. An extended facility at Soudan would provide an exciting opportunity for the generation of potential scientists now in school.

What are the broader impacts of the proposed activity?

The authors have made this proposal "explicitly broad in scope and goals" and it seems likely that the project would foster quite close interaction between basic science and technology. The construction and operation of such a facility cannot proceed without the development of experimental and engineering techniques of a rather challenging nature, such as the development of mechanisms to maintain huge volumes of ultra-pure water deep undergound for periods measured, perhaps, in decades, or the development of ultra-low radioactivity test facilities.

Outreach to the community around Soudan is well-established. The authors note, for example, that in 2002 some 6000 members of the public and school groups visited Soudan. It is not farfetched to imagine that the numbers would increase were Soudan to become a national laboratory. The authors point to the successful contacts between the Soudan facility and national and international media organizations. One would expect such associations to continue.

It seems likely that this project would have broad impacts in the sense of technology transfer and outreach. However, while one can see more clearly the impact of basic science on technological and engineering innovation, it is less clear what the societal impact of the proposed outreach is, other than that of informing the public. This is not a criticism of this proposal; the Soudan community is doing a fabulous job of informing the public. It is rather a plea to those who are in a position to do something about it to explain what it is they, or their masters, expect from such activities beyond public education.

Summary Statement

The authors propose building a multipurpose underground laboratory to conduct scientific investigations in nuclear physics, particle physics and goescience by extending the existing facility at Soudan. The science to be done is first-rate, an opinion shared by numerous high-level review panels. The authors of this proposal, who are highly competent and experienced scientists, have presented to date the

most credible plan for building a national underground laboratory, a crucial element of which is Phase 2, which will extend the Soudan facility to much greater depths.

Title:SOUDAN: A Proposal for a National Underground Science and Engineering Laboratory (NUSEL)

Institution: University of Minnesota-Twin Cities

NSF Program: Underground Physics

Principal Investigator: Marshak, Marvin L.

Rating: Excellent

Review:

What is the intellectual merit of the proposed activity?

The intellectual merit of the proposed activity is extraordinarily high. This is my personal belief and it has also been expressed by several panels of experts in this and related fields over the past several years. It is very much to be hoped that the United States will find a way to establish a first rate underground laboratory to pursue the important and varied science which such a laboratory will make possible.

What are the broader impacts of the proposed activity?

As is the case with all cutting edge science, involving sophisticated equipment development, it is expected that there will be important benefits to our overall technology and opportunities for commercial development of some of these technologies. In addition, the proposers have done a good job of planning to involve students of all levels in the exciting science and engineering which would exist at the laboratory, as well as planning to provide opportunities for the public in general to share in the excitement. The fact that the Soudan mine is already an historic site which is visited by the public makes this relatively straightforward.

Summary Statement

As stated above, I believe that the scientific case for a National Underground Laboratory is extremely strong. The Soudan proposal appears to be an excellent one, and I have no doubt that, if funded, it would succeed in taking advantage of the important scientific opportunities. I have previously reviewed similar proposals for laboratories at Homestake and at San Jacinto. In those cases I also rated them as excellent, because they also appear well designed to take advantage of the key scientific opportunities. Clearly there are political, economic, and ease of construction issues which distinguish these three proposals, and I have neither the information nor the expertise to make useful detailed comments on those differences. I will restrict myself here to commenting on those aspects of the Soudan proposal which bear upon its scientific potential.

There are two aspects of the Soudan proposal which could enhance or handicap the laboratory's scientific potential with respect to other site options. The first is the